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EFFECT OF INJECTION MOLDING PARAMETERS ON WELD LINE TENSILE STRENGTH

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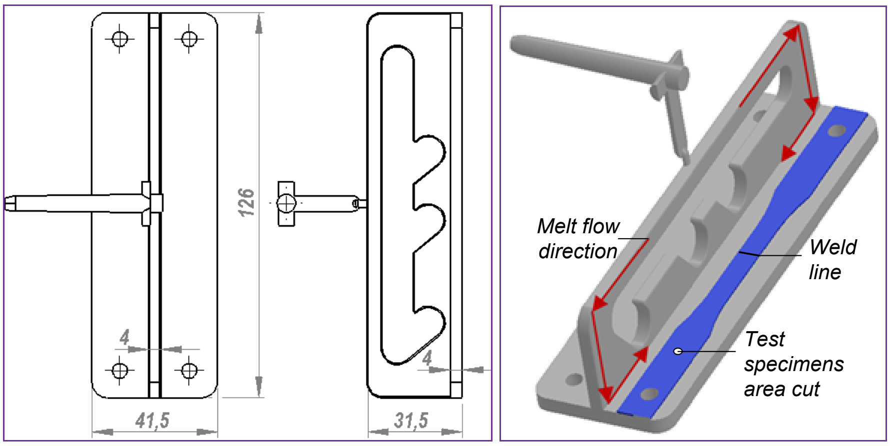
ABSTRACT
The weld line is an inevitable defect in the most injection molded components. It is a zone with reduced mechanical properties negatively influencing on the molding behavior in exploitation. The effect of: melt temperature, holding pressure and time, injection velocity and cooling time on the weld line tensile strength is analyzed in this paper. The material of the moldings was high density polyethylene (HDPE). The results showed that the holding pressure, injection velocity, melt temperature and cooling time have significant influence on tensile strength.
Keywords: injection molding, molding parameters, tensile strength

1. INTRODUCTION
Injection molding is a process where thermoplastics are formed in the desired shape by injecting molten material under high pressure into the mold cavity. The injection molding process consists: filling, holding pressure and cooling phases. Each phase has an influence on properties of the moldings. Molded part mechanical properties, particularly for crystalline materials, depend on: crystallization degree, crystalline size, molecular concentration and orientation of the linear molecular chains [1]. Weld line is a position on the molding where separated melt streams are joined. At the time of separated flows joining the melt on this zone is relatively colder [2]. The strength of weld line depends on: melt front speed, temperature, flow direction, residual stresses, etc. Generally, the weld line cannot be avoided, but its position as well as the mechanical properties can be influenced by gate location(s) and process parameters choice.

2. EXPERIMENTAL WORK
Molded components were produced on the ARBURG ROUNDER 221E/170R injection molding machine. The material used is HDPE, which belongs to the group of crystalline polymers. The basic characteristics of HDPE are: linear structural chain, high criystallinity and fair hardness, strength and stiffness.

Geometrical characteristics and 3D models of part, sprue, runner and gate, with position of test specimens on the molding are shown in Figure 1.



a) b)

Figure.1.Dimensions a) and 3D model b) of the molding

Parameters and their variation levels used in the injection molding experiments are given in Table 1. Injection molding experiments were conducted according to L9 plan using three repeats for each parameters.

Table.1. Parameters used in injection molding experiments

Injection Parameter	Unit	Level 1	Level 2	Level 3
Melt temperature (Tm)	^{o}C	190	200	-
Holding pressure (hydraulic) (Phn)	bar	35	45	55
Injection velocity (Vi)	mm/s	30	33	36
Holding pressure time (tpn)	s	3,5	4,5	5,5
Cooling time (th)	s	16	19	22

After injection molding specimens were cut out from the weld line zone area (Figure 1b). Uni-axial tensile tests were conducted according to the ISO 527-2 standard on the Zwick/Roell Z030 testing machine. The melt front position at time and finally weld line position were predicted numerically (Figure 2a) and confirmed experimentally (Figure 2b).

a) b)

Figure.2. Melt flow and weld line location: numerical a) and experimental b)

3. RESULTS AND DISCUSSION

The tensile strength mean values with standard deviations are given in Table 2. The main effects of: melt temperature (Tm), holding pressure (Phn), injection velocity (Vi), holding pressure time (tpn) and cooling time (th) are shown on Figure 3. From main effect plot it is clear that melting temperature, holding pressure and injection velocity increase resulted in linear increase of weld line zone tensile strength. However, tensile strength linearly decreases with increasing part cooling time in the mold.

Table.2. Tensile strength and standard deviation mean values

No.	Tensile strength [MPa]	S_{TDE}	No.	Tensile strength [MPa]	S_{TDE}
1	19.45	0.207	10	19.14	0.717
2	18.93	0.534	11	18.78	0.255
3	18.88	0.900	12	19.54	0.760
4	18.95	0.358	13	19.48	0.568
5	19.84	0.897	14	20.77	0.255
6	20.70	0.710	15	21.10	0.203
7	20.14	0.689	16	20.90	0.684
8	20.82	1.193	17	21.03	0.152
9	20.98	0.623	18	22.23	0.203

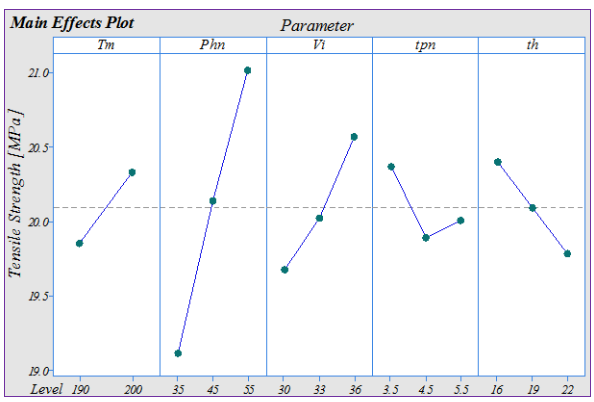


Figure.3. Parameter influence character

The results of the analysis of variance (ANOVA) are shown in Table 3.According to ANOVA results parameters that have significant influence on weld line zone tensile strength are: holding pressure (p=0.000..), injection velocity (p=0.007), melt temperature (p=0.022) and in-mold cooling time (p=0.048).

Table.3. Medium tensile strength analysis variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Tm	1	1.0098	5.86%	1.0098	1.0098	8.02	0.022
Phn	2	10.8479	62.97%	10.8479	5.4240	43.10	0.000
Vi	2	2.4579	14.27%	2.4579	1.2289	9.77	0.007
tpn	2	0.7549	4.38%	0.7549	0.3774	3.00	0.107
th	2	1.1489	6.67%	1.1489	0.5744	4.56	0.048
Error	8	1.0068	5.84%	1.0068	0.1258		
Total	17	17.2262	100.00%				

(α = 0.05 - Factor of significance)

Experimental results showed that as melt temperature increase the tensile strength of weld line zone also increase. This can be explained by more effective bonding of separated flows at higher temperatures. The effect of injection velocity is similar. Higher velocity lead to more viscous heating, which additionally increases melt temperature and consequently facilitate bonding of the weld line zone.

Holding pressure is the most influencing parameter on the weld line tensile strength. Higher pressure resulted in increased density and degree of crystallinity [3,4]. Also, as the pressure increase better molecular bonding and higher molecules concentration occurred, which can explained increase of the tensile strength.

The cooling time determines the cooling rate, thus directly affecting crystals formation. As a consequence of shorter cooling time, reduced molecular mobility and formation of large number of smaller crystal-lite (spherulite) occurred. Since, spherulitic structure has higher tensile strength compared to not complete crystalline structures with more amorphous regions [3], shorter in-mold cooling time resulted in increase of tensile strength.

4. CONCLUSIONS

- Tensile strength of the weld line zone increases with increase of melt temperature, injection velocity, and holding pressure.
- Tensile strength of the weld line zone decreases with increase of in-mold cooling time.
- For variation range of parameters used in injection experiments holding pressure is a most influencing parameter on weld line zone tensile strength with (62,97 %) contribution in the total variation. Contributions sum of injection velocity, melt temperature and in-mold cooling time is 26,80 %.

5. REFERENCES

[1] Subodh Singh Tomar, Ashish Kumar Sinha, Ashish Shrivastava; Parametric Study of Injection Moulding Using Polypropylene H200mk Grade, International Journal of Science, ISSN: 2455-0108, www.ijoscience.com Volume II Issie III june 2016.

[2] Robert A. Malloy; Plastic Part Design for Injection Molding, An Introduction 2nd Edition, Carl Hanser Verlag, Munich 2010.

[3] Mani, Mohammad Reza (2016); Investigating the effect of process parameters on dimensional accuracy and ultimate tensile strength of micro injectionmoulded micro parts PhD thesis, University of Nottingham.

[4] Vannessa Goodship; ARBURG Practical Guide to Injection Moulding, 2nd Edition, First Published in 2017.